

CLAIMS

1. An apparatus for sensing motion of a reference surface, comprising:
a shell, a case within the shell, and a suspension;
wherein the mass of the case is greater than the mass of the shell, and wherein the case is coupled to the shell with the suspension; and
a first electrode coupled to the shell, wherein the first electrode is configured to detect relative motion between the first electrode and the case.
2. The apparatus of claim 1, wherein the shell is substantially cylindrical having an axial direction and a radial direction perpendicular to the axial direction.
3. The apparatus of claim 2, wherein the suspension comprises a closed cell foam.
4. The apparatus of claim 3, wherein the closed cell foam is about 100 times stiffer in the radial direction, than in the axial direction.
5. The apparatus of claim 3, wherein a stiffness of the closed cell foam in the axial direction is such that a resonance frequency of the case in the axial direction is at a low frequency cutoff.
6. The apparatus of claim 1, wherein the shell comprises polyvinyl chloride.
7. The apparatus of claim 1, wherein the case comprises tungsten.
8. The apparatus of claim 1, wherein the suspension comprises closed cell foam.
9. The apparatus of claim 8, wherein the closed cell foam is about 100 times stiffer in a radial direction than in an axial direction, wherein the radial direction is perpendicular to the axial direction.
10. The apparatus of claim 8, wherein a stiffness of the closed cell foam in an axial direction is such that a resonance frequency of the case in the axial direction is at a low frequency cutoff.

11. The apparatus of claim 1, further comprising: a battery disposed within the case.
12. The apparatus of claim 1, wherein the first electrode produces a signal responsive to a relative motion between the first electrode and the case.
13. The apparatus of claim 12, further comprising: a charge amplifier, wherein the charge amplifier amplifies the signal.
14. The apparatus of claim 1, wherein the first electrode comprises a metal foil.
15. The apparatus of claim 1, further comprising: a fluid disposed between the shell and the case.
16. The apparatus of claim 15, wherein the fluid has a relative dielectric coefficient greater than about 2.
17. The apparatus of claim 15, wherein the fluid has a relative dielectric coefficient greater than about 78.
18. The apparatus of claim 15, wherein the fluid has a viscosity greater than about 1.0 centipoise.
19. The apparatus of claim 15, wherein the fluid has a viscosity greater than about 10.0 centipoise.
20. The apparatus of claim 15, wherein the fluid is ethylene glycol.
21. The apparatus of claim 15, wherein the fluid increases a capacitance of the first electrode.
22. The apparatus of claim 15, wherein the fluid damps the relative motion between the case and the first electrode.
23. The apparatus of claim 1, further comprising a second electrode coupled to the shell.
24. The apparatus of claim 23, wherein the first electrode is positioned at a top of the shell and the second electrode is positioned at a bottom of the shell.

25. The apparatus of claim 1, wherein the first electrode functions by electrostatic signal transduction.
26. The apparatus of claim 1, wherein the mass of the case is at least two times greater than the mass of the shell.
27. The apparatus of claim 1, wherein the mass of the case is at least ten times greater than the mass of the shell.
28. An apparatus for sensing motion of a reference surface, comprising:
- a shell, a case within the shell, and a suspension; wherein the mass of the case is greater than the mass of the shell, and wherein the case is coupled to the shell through the suspension;
 - a first electrode coupled to the shell; and
 - a second electrode coupled to the case;
- wherein the first and second electrodes are configured to move relative to each other, thereby producing a signal representing the relative motion between the first and second electrodes.
29. The apparatus of claim 28 wherein the shell is substantially cylindrical.
30. The apparatus of claim 29 wherein a radius of the shell is less than a height of the shell.
31. The apparatus of claim 30 further comprising: a cone shaped end.
32. The apparatus of claim 31 further comprising: a battery disposed in the cone shaped end.
33. The apparatus of claim 32 further comprising: a damper disposed between the battery and the shell, whereby a mass of the battery is isolated from a mass of the shell.
34. The apparatus of claim 28 further comprising: a fluid disposed between the shell and the case.

35. The apparatus of claim 34 wherein the fluid has a relative dielectric coefficient greater than about 2.
36. The apparatus of claim 34, wherein the fluid has a relative dielectric coefficient greater than about 78.
37. The apparatus of claim 34, wherein the fluid has a viscosity greater than about 1.0 centipoise.
38. The apparatus of claim 34, wherein the fluid has a viscosity greater than about 10.0 centipoise.
39. The apparatus of claim 34, wherein the fluid is ethylene glycol.
40. The apparatus of claim 34, wherein the fluid increases a capacitance of the first and second electrodes.
41. The apparatus of claim 34, wherein the fluid damps the relative motion between the case and the shell.
42. The apparatus of claim 34, further comprising: an orifice ring disposed between the shell and the case.
43. The apparatus of claim 42, wherein the orifice ring is configured to provide increasing fluid flow resistance as a relative velocity between the case and the shell increases.
44. The apparatus of claim 28, further comprising: a radio coupled to the shell.
45. The apparatus of claim 28, wherein the mass of the case is at least two times greater than the mass of the shell.
46. The apparatus of claim 28, wherein the mass of the case is at least ten times greater than the mass of the shell.
47. A method for deploying a sensor apparatus, comprising:

disposing the sensor apparatus onto a reference surface whereby the sensor apparatus self-couples to the reference surface; wherein the sensor apparatus comprises,

a shell, a case within the shell, and a suspension; wherein the mass of the case is greater than the mass of the shell, and wherein the case is coupled to the shell through the suspension;

and an electrode is coupled to the shell, wherein the electrode is configured to detect relative motion between the electrode and the case.

48. A method for deploying a sensor apparatus, comprising:

disposing the sensor apparatus onto a reference surface, whereby at least a portion of the sensor apparatus penetrates the reference surface thereby self-coupling to the reference surface; and wherein the sensor apparatus comprises,

a shell, a case within the shell, and a suspension; wherein the mass of the case is greater than the mass of the shell, and wherein the case is coupled to the shell through the suspension;

a first electrode coupled to the shell; and

a second electrode coupled to the case;

wherein the first and second electrodes are able to move relative to each other, thereby producing a signal representing the relative motion between the first and second electrodes.

49. The method of claim 48, wherein the sensor apparatus further comprises a radio coupled to an end of the shell, and wherein the radio does not penetrate the reference surface.